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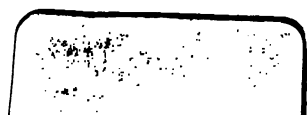
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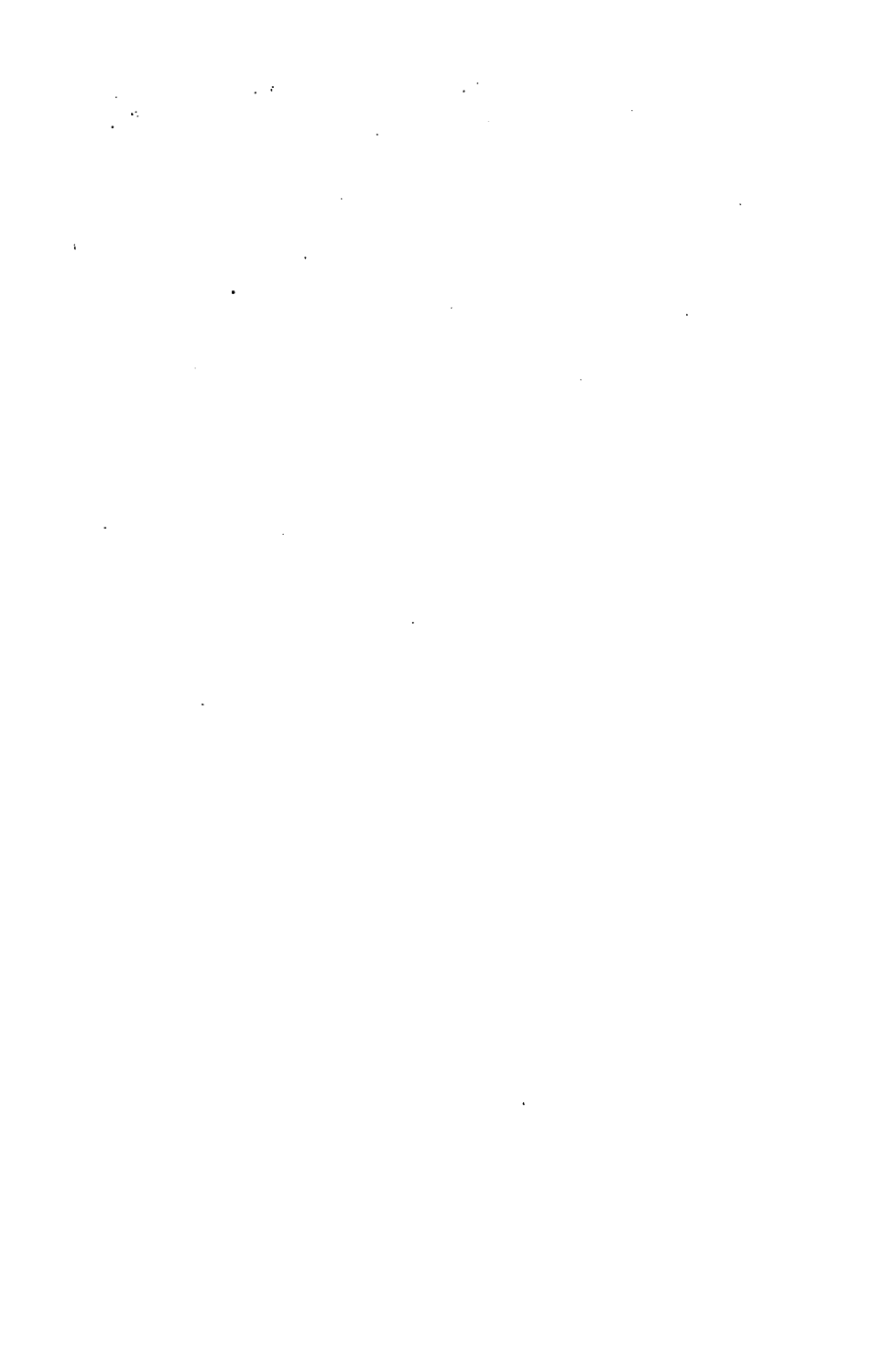
# PHYSIOLOGICAL CHEMISTRY

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S. W. MOORE













# **PHYSIOLOGICAL CHEMISTRY**





NOTES OF DEMONSTRATIONS  
ON  
PHYSIOLOGICAL CHEMISTRY

BY  
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'DEMONSTRATION IS THE BEST MODE OF INSTRUCTION'

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LONDON  
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1874

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193. 9. 81.



## PREFACE.

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THE regulation of the Royal College of Surgeons affecting instruction on physiology caused a demand for text-books, which was very readily responded to; excellent indeed as some of these books are, yet they do not supply the want felt by the average medical student, viz., hints as to which are the most important points in practical work which he can be expected to acquire.

It is impossible for a class of men with only three hours a week at its disposal for practical work, to go through lengthy and uninteresting processes; it was, then, to meet this difficulty that I compiled these notes, so arranging them as to show the student methods that more nearly concern his immediate and future requirements.

It is not intended that processes should be fully described here, but only noted so that the student when in the laboratory may have with the aid of the demonstrator a fair guide to the acquirement of useful practical knowledge; it is also presumed that he has gained a fair knowledge of general chemistry previously to his undertaking the work figured in this book.

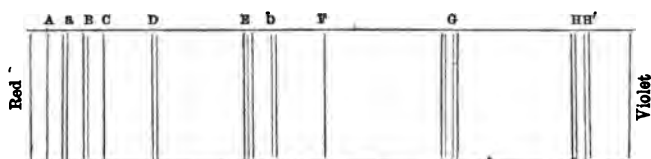


*List of Elementary Bodies, with Atomic Weights and Symbols.*

*Aluminium . . .	Al	27·5	Molybdenum . . .	Mo	92·
Antimony . . .	Sb	122·	Nickel . . .	Ni	58·8
Arsenic . . .	As	75·	Niobium . . .	Nb	97·6
Barium . . .	Ba	137·	*Nitrogen . . .	N	14·
Beryllium . . .	Be	14·	Osmium . . .	Os	199·
Bismuth . . .	Bi	208·	*Oxygen . . .	O	16·
Boron . . .	B	11·	Palladium . . .	Pd	106·5
Bromine . . .	Br	80·	*Phosphorus . . .	P	31·
Cadmium . . .	Cd	112·	Platinum . . .	Pt	197·4
*Calcium . . .	Ca	40·	*Potassium . . .	K	39·
*Carbon . . .	C	12·	Rhodium . . .	Rh	104·
Cerium . . .	Ce	92·	Rubidium . . .	Rb	85·5
Cæsium . . .	Cs	133·	Ruthenium . . .	Ra	104·
*Chlorine . . .	Cl	35·5	Selenium . . .	Se	79·
Chromium . . .	Cr	52·5	*Silicon . . .	Si	28·5
Cobalt . . .	Co	58·8	Silver . . .	Ag	108·
*Copper . . .	Cu	63·5	*Sodium . . .	Na	23·
Didymium . . .	Di	96·	Strontium . . .	Sr	87·5
Erbium . . .	Er	112·6	*Sulphur . . .	S	32·
*Fluorine . . .	Fl	19·	Tantalum . . .	Ta	137·5
Glucinum . . .	G	9·	Tellurium . . .	Te	128·
Gold . . .	Au	196·7	Thallium . . .	Tl	204·
*Hydrogen . . .	H	1·	Thorium . . .	Th	231·3
Iodine . . .	I	127·	Tin . . .	Sn	118·
Iridium . . .	Ir	198·	Titanium . . .	Ti	50·
*Iron . . .	Fe	56·	Tungsten . . .	W	184·
Lanthanium . . .	La	92·	Uranium . . .	U	120·
Lead . . .	Pb	207·	Vanadium . . .	V	51·2
Lithium . . .	Li	7·	Yttrium . . .	Y	68·
*Magnesium . . .	Mg	24·	Zinc . . .	Zn	65·
*Manganese . . .	Mn	55·	Zirconium . . .	Zr	90·
Mercury . . .	Hg	200·			

\* \* The elements marked thus (\*), are contained in the animal body.

*Map of Spectrum, showing the Relative Positions  
of some of Fraunhofer's Lines.*



*Centigrade and Fahrenheit Thermometer Scales  
Compared.*

Centigrade		Fahrenheit
100°	—	212° water boils.
90°	—	194°
80°	—	176°
70°	—	158°
60°	—	140°
50°	—	122°
40°	—	104°
30°	—	86°
20°	—	68°
10°	—	50°
0°	—	32° water freezes.

To convert Centigrade to Fahrenheit, multiply by 1·8 and add 32°,  
i.e., 40° C.  $\times$  1·8 = 72·0 + 32 = 104° F.

### *Metric System of Weights and Measures.*

To change an Imperial Yard to a Metre  $\times 0.914383$

„ Gallon to a Litre  $\times 4.543457$

„ Cubic Inch to a Litre  $\times 0.016386$

Unit of weight one gramme = 15.432 grains troy

„ length one metre = 39.371 inches

„ capacity one litre = 0.880 quart

The prefixes Myria (10,000), Kilo (1,000), Hecto (100), Dekka (10), multiply the units before which they are placed; whilst the prefixes Deci (0.1), Centi (0.01), and Milli (0.001) divide, that is, reduce the aforesaid units.





# NOTES

ON

## PHYSIOLOGICAL CHEMISTRY.

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OF the sixty-four elementary bodies which have been found in the earth, seventeen only take part in the formation of the animal economy, viz. carbon, hydrogen, nitrogen, oxygen, chlorine, fluorine, sulphur, silicon, and phosphorus, the so-called non-metals or metalloids; and potassium, sodium, magnesium, calcium, aluminium, iron, manganese, and copper, the metals.

Animals assimilate the food upon which they exist in such a manner that the compounds produced are so complex and variable as to distinguish them from those of the vegetable kingdom. It is generally agreed that vegetable products are ternary compounds ( $\text{CHO}$ ), while animal substances are quarternary ( $\text{CHNO}$ ); this is an arbitrary division, though to a great extent true,

for in many instances vegetable products are very complex, yet they never reach the high atomic weights found in the animal kingdom.


The compound elements formed out of the above-named simple bodies are termed *proximate* elements, to distinguish them from the *ultimate* elements.

The animal body, taken as a whole, is specifically lighter than water.

It contains seven-eighths by weight of water, which may be removed by drying on a water-bath.

The inorganic matter may be estimated at about three per cent. Brunetti found in his experiments on cremation that the body of a woman, aged 35 years, and weighing 110lbs., yielded  $4\frac{1}{2}$ lbs. of ash; and that of a man, aged 45 years, and weighing 90lbs., yielded  $2\frac{1}{2}$ lbs. of ash.

To obtain the ash of an animal substance it is necessary to dry well on a water-bath, and subsequently in an air-bath, then to char at a low temperature, wash well with distilled water; save the washings for subsequent evaporation, as they contain some of the soluble salts; then incinerate completely after a second drying. It is often necessary, before all the carbon is removed, to expose the substance of which the ash is required for hours in a muffle at a low red heat.



For a method of analysing the ash, the student is referred to Fresenius' Quantitative Analyses.

It is frequently necessary to know of what elements a substance may be composed, *i.e.*, whether it contains sulphur, nitrogen, or other elements. The following are simple qualitative tests for some of the more important ones.

*Carbon* is proved by the charring and smoky luminous flame on burning and formation of carbonic acid.

*Nitrogen* by the evolution of certain odours peculiar to nitrogenous substances, and familiar as the 'burnt horn' smell; the presence of nitrogen is more certainly proved by the production of ammonia ( $\text{NH}_3$ ) when the substance is heated with caustic potash ( $\text{KHO}$ ).

*Chlorine*.—Substances containing this element need to be reduced to ash; this is dissolved in distilled water, and tested with nitrate of silver; the chloride of silver is precipitated, if chlorine be present, and is soluble in ammonia ( $\text{NH}_3$ ).

*Sulphur* may be demonstrated by boiling the suspected substance with liquor potassæ and a solution of acetate of lead; the sulphide of lead precipitates.

Another method is to deflagrate the substance with pure chlorate of potass. Dissolve the residue in dis-

tilled water, and test for the sulphuric acid, formed by oxidation of the sulphur, with barium chloride; an insoluble precipitate of barium sulphate is formed.

*Phosphorus* may be found in the above residue if present in the original substance.

The metals are readily proved in the ash by the ordinary tests.

The seventeen ultimate elements are distributed variously; thus carbon, hydrogen, nitrogen, and oxygen are found in most tissues; sulphur principally in albumin; phosphorus in bone and brain; chlorine in juices as chlorides; fluorine and silicon in bone and teeth, with calcium, magnesium, and aluminium; sodium and potassium in juices and blood; iron also in blood; manganese in hair; copper in liver and bile. These are only general statements, the elements of course varying in every tissue either in number or proportion.

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The most important proximate elements, both chemically and physiologically, are the albuminous bodies; these have undoubtedly most complicated formulæ, which makes them easily subject to chemical changes, so as to fit them for the purposes to which they are applied.

*Albumin*, most familiar to us as white of egg, is

capable of existing in various states; thus there are several compounds closely resembling it in composition, which determines them to the same group.

Albumin exists in a neutral, acid, and alkaline condition, the special tests for and properties of which we will briefly consider.

Mulder originally stated that a substance called protein existed as the base of all albuminous bodies; he gave it a formula of  $C_{18}H_{28}N_4O_{51}H_2O$ , and declared it to be free from sulphur; he prepared it by dissolving albumin in potassic hydrate and precipitating with acetic acid; subsequent observers have been unable to prepare it free from sulphur.

Gerhardt considers soluble egg albumin to be thus constituted:— $HNaC_{72}H_{112}N_{18}SO_{22}H_2O$ .

Albumin may be obtained in a fairly pure condition by dialysing egg albumin. This process consists in floating a drum of parchment paper containing white of egg on distilled water; the salts nearly all pass through the membrane, and leave a tolerably pure substance behind; this may be evaporated to dryness at  $40^{\circ} C.$ , and preserved; it is a brittle yellow transparent substance soluble in water.

Albumin proper coagulates at  $60^{\circ} C.$  in the presence of water; it is precipitated from solution by all the mineral acids except trihydric phosphate; it is

## 6 *Notes on Physiological Chemistry.*

soluble in concentrated mineral acids; nitric acid forms with it xanthoproteic acid, which gives an orange colour with ammonia; the solution in hydrochloric acid assumes a blue colour, while that in sulphuric acid is of a dark brown.

It is precipitated by an excess of strong alcohol, by kreasote, ether, phenol, and the salts of the heavy metals;  $\frac{1}{2000}$ th part in solution may be detected by mercuric chloride, so that it constitutes an excellent antidote to poisoning by salts of the heavy metals, as lead, copper, and mercury.

Not any of the organic acids precipitate albumin, save tannic acid; the most delicate test, however, is ferrocyanide of potassium in the presence of acetic acid.

Albumin, when ingested in large quantities or injected under the skin, appears in the urine.

The most useful and more generally applied of the above tests, are—heat, nitric acid, ferrocyanide of potassium in the presence of acetic acid and the xanthoproteic reaction; these two latter detect the merest traces. It may be estimated quantitatively by boiling, filtering, and weighing the dried precipitate.

Alkali albumin may be formed by dissolving albumin in liquor potassæ by the aid of heat; it contains no sulphur (?), is not precipitated by boiling,

precipitates when neutralized, and is soluble in dilute acids.

It is probable that albumin always exists in solution as an alkaline salt; thus, when white of egg is boiled, and albumin coagulated, alkali is always set free.

Alkali albumin is not precipitated in the presence of alkaline phosphate; carbonic anhydride, sulphate of magnesium, and calcium chloride, precipitate it; acetic acid causes a precipitate (protein ?) after neutralization.

Acid albumin, syntonine or muscle fibrine, is formed by dissolving albumin in dilute acids, or it may be obtained from muscle by mincing a portion of flesh freed from fat, and digesting in dilute acid for some hours, filtering and neutralizing with sodium carbonate, a precipitate of syntonine occurs.

Unlike alkali albumin, alkaline phosphates do not affect its precipitation; when nearly neutralized it is precipitated by boiling; it is not precipitated by magnesium sulphate or calcium chloride except on boiling, which process converts it into alkali albumin.

The presence of acid or alkali affects the coagulability of albumin; thus if three portions of albumin, one acid, another neutral, and the remaining one



## 8      *Notes on Physiological Chemistry.*

alkaline, be subjected to heat, they will coagulate in the above order.


There are other forms of albumin which are important in their places; they are not, however, so very different in their behaviour towards tests as to warrant a separate description; these are paralbumin, globulin, vitellin, myosin, fibrinogenic and fibrinoplastic substances.

Albumin and its allies readily decompose and yield some most penetrating and disgusting odours. Amongst other products, leucine and tyrosine generally occur whether the decomposition be putrefactive or chemical.

### ALBUMINOID BODIES.

*Leucine*,  $C_6H_{13}NO_2$ , is a white body occurring in pearly scales. It may be prepared as follows:—Boil one part of cowhorn shavings with four parts of concentrated sulphuric acid and twelve parts of water for some hours. Add an excess of milk of lime; boil, strain, and press. Mix the filtrate with very slight excess of sulphuric acid, and evaporate. Tyrosine first separates, and subsequently leucine.

Leucine sublimes on the application of heat, is soluble in hot water, insoluble in alcohol. Tyrosine,



$C_9H_{11}NO_3$ , soluble in boiling water, insoluble in alcohol, gives a pink colour and red precipitate with a mixture of mercurous and mercuric nitrates.

*Gelatinous* or albuminoid bodies generally occupy a stationary position in the economy, *i.e.*, not serving to nourish nor passing off as waste, but forming the mechanical supports, or acting mechanically in the various parts of the body.

Bones yield much gelatin; hides, skin, hoofs, nails, and tendons, also supply it; the gelatinous base of the last three is known as keratin.

Gelatin may be prepared by boiling bones for a long time in a Pappin's digester, under a pressure of two or three atmospheres; prolonged boiling, however, affects the property it has of gelatinising, which is, of course, its great characteristic; isinglass and glue are other forms of the same thing.

*Gelatin* is readily soluble in hot water, and gelatinises on cooling if the solution contains one per cent.; it is insoluble in cold water, but swells up when soaked in it.

Moist gelatin readily absorbs salts, such as tricalcic phosphate ( $Ca_32PO_4$ ); tannic acid, mercuric chloride, alcohol, and chlorine gas, precipitate it.

Boiled with sulphuric acid, it is converted to glycocoll (glycocin).

*Chondrin*, closely allied to gelatin, is obtained from cartilage; it contains less oxygen, and differs in being precipitated by acetic acid, alum, and plumbic acetate; sodium chloride redissolves the acetic acid precipitate.

Permanent and foetal cartilage are both composed of it; the latter, however, only before ossification takes place.


*Mucin* is a constant element of mucus; it is contained in foetal connective tissue and in tendon; acetic acid precipitates it, and causes it to contract.

#### DECOMPOSITION PRODUCTS.

These bodies are very various in composition, but are probably all the result of waste of tissue.

*Urea*,  $\text{CH}_4\text{N}_2\text{O}$ ; colourless, crystallises in prisms, deliquescent; it is metamerie with ammonium cyanate ( $\text{NH}_4, \text{CNO}$ ), and may be formed from it by evaporating a solution to dryness over a water-bath. Urea contains more nitrogen than any other definite chemical compound, and is thus the means of conveying away the waste nitrogen; it is contained most abundantly in the urine, in lesser quantities in the blood, and traces in the sweat (Stark).

The urine of carnivora contains it in greater abun-



dance than that of other animals. Heated to  $120^{\circ}\text{C}$ . urea melts; at a somewhat higher temperature it decomposes. Ammonia, and cyanate, and carbonate of ammonium are formed, and cyanuric acid is left in the retort. At a still higher temperature melanuric acid is produced, and this by heat is converted to mellon ( $\text{C}_9\text{N}_{13}$ ), familiar to us as the yellow coating of Pharaoh's serpents.

Biuret is obtained by heating urea to  $170^{\circ}\text{C}$ . It is very stable, and may be dissolved in concentrated mineral acids without decomposition.

Urea combines with both acids and bases, in one case forming such bodies as nitrate of urea, and in the other such as the mercuric salt ( $2\text{CH}_4\text{N}_2\text{O}$ ,  $3\text{HgO}$ ).

*Kreatin* ( $\text{C}_4\text{H}_9\text{N}_3\text{O}_2$ ,  $\text{H}_2\text{O}$ ) is found in the juice of muscle and in urine; it may be obtained from the flesh of codfish in the proportion of about five grains to 1lb. of flesh; it is insoluble in cold alcohol.

Kreatinine ( $\text{C}_4\text{H}_7\text{N}_3\text{O}$ ) is a derivative of kreatin, and may be obtained from it by boiling with dilute hydrochloric acid.

Sarkin, xanthine, and guanin are similar bodies, but unimportant so far as the general student is concerned.

*Uric acid* ( $\text{C}_5\text{H}_4\text{N}_4\text{O}_3$ ) is a white crystalline powder, one part soluble in 10,000 of water; it crystal-

lises in rhombic plates, frequently modified by the presence of colloid matter, so that lozenges, stars, crenated plates, &c., are formed.

It combines with bases to form salts, as urate of ammonium.

Uric acid occurs abundantly in the excrement of serpents, which consists chiefly of urate of ammonium.

It is contained in healthy urine, in blood, and traces in sweat; in the so-called uric acid diathesis it is very abundant in the blood. It is then frequently precipitated from the urine in red grains, the so-called 'Cayenne pepper' grains. In gout it is secreted in the synovial membranes, as urate of lime, commonly called 'chalk stones.' It is hardly necessary to add that not any carbonate of lime is present in them.

Uric acid may be obtained from urine by evaporating to one-fifth the bulk, and adding hydrochloric acid, which precipitates it as a crystalline powder.

Dr. Garrod recommends, as a method to determine its presence in blood, to acidulate with acetic acid, and to lay in it a piece of thread, upon which, in the course of about twelve hours, crystals will collect; this test is conveniently carried out in a watch-glass.

To prepare pure uric acid in quantity, boar excrement should be dissolved in liquor potassæ, and hydrochloric acid added. The precipitate formed is uric

acid, which may be redissolved and again precipitated until pure.

Uric acid is very prolific in decomposition products. These, though full of interest to the chemist, are not of so great importance to the medical student, and one change only need be mentioned. When uric acid is dissolved in strong nitric acid in the cold, crystals of a body called alloxan are formed; these, by exposure to light, change to a pink colour; if the nitric acid solution of uric acid be evaporated to dryness, and a solution of ammonia be added, a purple colour is developed, which is murexide or purpurate of ammonia; if a solution of potash is added, either before or after this reaction, to the residue, a fine violet colour is produced. These are the most delicate tests for uric acid that have been devised, and may be demonstrated on the smallest visible particles.

*Hippuric acid* ( $C_9H_9NO_3$ ) is excreted from the system in the urine; it may be abundantly produced in man by the ingestion of benzoic acid.

The probable composition and arrangement of hippuric acid is  $C_2H_2(NH_2)(C_7H_5O)O_2$ , in which the radical benzoyl takes the place of an atom of hydrogen in glycocine.

The glycocine and benzoic acid probably produced

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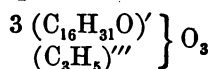
in the system thus combine to form a new excrementitious body.

When hippuric acid is heated in a test tube it decomposes and forms benzoic acid and an oily body, benzonitrile, having the odour of Tonka beans.

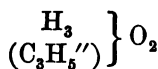
Ferric chloride produces a cinnamon brown precipitate of ferric hippurate with a solution of a neutral hippurate.

### FATS.

*Fats* are compounds in which the three replaceable atoms of hydrogen in the triatomic alcohol glycerine are exchanged for three monatomic radicals of the fatty acids, such is tripalmitine,



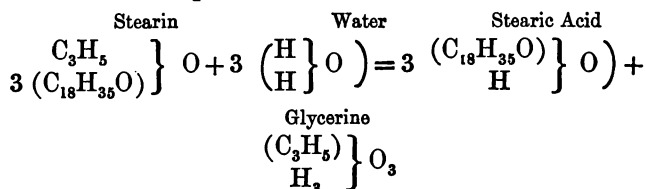
in which the three atoms of hydrogen in glycerine



are displaced by the radical of palmitic acid.

*Glycerine* is a viscid fluid soluble in water in any proportion; it has remarkable solvent properties for active principles, extractive matters, &c.; it does not dry, and on heating it with glacial acetic acid it decomposes and forms acrolein, a very acrid and irritating compound, whereby glycerine may be shown, as it alone produces this body.

Glycerine may be set free by saponification or by the action of superheated steam under high pressure.



The saponification of fats consists in treating with some base that sets free the glycerine by combining with the fatty acid.

The rancidity of fats is due to the action of contained albumin which sets free small portions of butyric acid, &c.

Fatty matters are variously soluble, some in cold alcohol, some in boiling alcohol, but the majority are soluble in ether, benzol, and chloroform.

Fats are differentiated more particularly by their melting points; the method of ascertaining this is as follows:—Make a capillary tube, by heating in a gas flame until red-hot a piece of quill tubing, and then suddenly drawing asunder the two ends; between these will then exist a fine capillary tube, which may be broken up into four-inch lengths; the end of one of these should be introduced into a portion of the melted fat, the melting point of which it is desirable to determine; the tube immediately draws into itself a



portion of the fluid fat, which solidifies as soon as the tube is removed from the heat.

The charged capillary tube should now be placed in a bath of oil having in it a thermometer, and heat should be applied to the bath (a glass beaker serves this purpose); at a certain temperature indicated by the thermometer, the solid fat in the tube becomes transparent, and this indicates that it has melted.


#### THE SPECTROSCOPE.

The spectroscope is one of the happiest discoveries of modern science. It has enabled the chemist to differentiate apparently identical bodies in the organic world, and has also opened to him the knowledge of the constituent elements of many of the heavenly bodies.

In animal chemistry its application is without parallel, so great are the advantages accruing from its use.

It will be necessary to mention before proceeding to the instrument itself, a few facts concerning light and its properties.

Light is considered to be some disturbing influence acting upon an all-pervading ether, and producing undulations or waves, which convey the sensation



called light to our retina; these waves are not progressive, but may be compared to the motion of a field of standing corn when agitated by a breeze. The known sources of light are the sun, stars, combustion, electricity, and phosphorescence. When vibrations of this ether are capable of being produced in a body, it is said to be transparent; when not so, opaque. Opaque bodies either absorb or reflect light. Polished metallic surfaces reflect about 95 per cent. of light received; the only instances of total reflection are the third face of a prism and the under surface of a transparent fluid when viewed at the so-called critical angle.

Light undergoes several modifications in passing through transparent bodies, the principal being refraction. In passing from a rare to a dense medium, it is refracted or bent towards the perpendicular; when passing from a dense to a rare medium, the reverse.

If a ray of light passes through a transparent body in the form of a prism, not only is the ray bent, but it is dispersed, that is, spread out like a fan, and the band no longer remains white, but consists of red, orange, yellow, green, blue, indigo, and violet; the violet is most refrangible, that is, bent aside most; these colours constitute the spectrum.

This spectrum proves the compound nature of

light; if these coloured rays be caught on a lens, they become condensed to a white light at the focus.

If differently coloured glasses be separately interposed between the spectrum and the screen, all light will be cut off, excepting the rays identical in colour with the glass.

There are four kinds of spectra—the *continuous*, as developed from lime light; the *interrupted*, when only certain bright lines appear; the *reversed*, when in the continuous spectrum black lines are seen; and the *absorption*, in which certain colours are absorbed and shadows take their place.

The sun gives a reversed spectrum; the black lines seen in this were discovered by Wollaston, but they are named after Fraunhofer, who was the first to count and map them out.

Rays of a given colour are always visible in the same part of the spectrum; thus, if we take a flame incapable of producing a spectrum (a Bunsen burner will give such), and burn in it some metal, as sodium, we shall have, not a perfect spectrum, but an interrupted—that is, bright lines will appear (in this case, yellow ones) at definite positions in the field. Each metal giving differently coloured rays, we are enabled to distinguish them very readily one from another.

The reversed spectrum is produced by the stronger



light of the continuous spectrum absorbing the weaker rays of the burning metal or gas. By comparing Fraunhofer's lines with the bright lines produced by incandescent vapours, we are enabled to tell the constituents of the sun's atmosphere.

Various bodies have the property of stopping the rays of light, and in this way producing black bands or spaces at different parts of the spectrum; these are called absorption bands.

Blood, chlorophyll, anilines, &c., gives spectra of this kind.

The spectrum has, at the red portion, heat rays; at the yellow part, light rays; and at the blue end, chemical or actinic rays. At the extreme violet there exists another kind of ray, which may be demonstrated with a solution of quinine, and is known as the fluorescent ray.

For rough work a very useful spectroscope may be improvised from an ordinary bisulphide of carbon prism put into a small circular box with a slit at one side for the incident ray, and a hole at the other, through which to observe the spectrum.

See woodcut for position of principal lines in spectrum.

**DIGESTION.**

The various tissues are nourished by food which has to undergo a series of changes in the alimentary canal before it can be utilised for the purpose.

The first process to which it is subjected, that of chewing or mastication, comminutes the food and mixes it with the saliva.

The *Saliva* is secreted by several glands situated in and about the mouth, and in its mixed condition is a viscid clear fluid, with an alkaline reaction to test-paper. It serves to moisten the mouth, to dissolve soluble substances, and acts as a ferment on starchy matters by virtue of an active principle.

It has a specific gravity of about 1.008; it contains about 99 per cent. of water; its inorganic constituents consist of carbonates, chlorides, and sulphates of potassium, sodium, calcium, and magnesium; sulphocyanide of potassium is secreted by the parotid gland.

The organic constituents are albumin, globulin, mucin, and ptyalin.

To obtain saliva for experiment, it is necessary either to excite the natural flow by stimulus, or to establish a fistula. For ordinary experiments, it is only necessary to fill the mouth with ether vapour,



which will occasion an abundant secretion; for experiments, however, on the secretions of individual glands, a canula must be inserted into the orifice of each duct, and the secretions collected in separate vessels.

The presence of sulpho-cyanogen may be demonstrated in saliva by the addition of a few drops of very dilute solution of perchloride of iron, which produces a blood-red colouration with this compound; the red colour is bleached by the addition of mercuric chloride.

The active principle ptyalin acts on starchy matter variously under different conditions of temperature. The normal heat of the body encourages the action, while cold retards, and excessive heat altogether destroys it. This may be shown by mixing some mucilage of starch with saliva in three test-tubes, placing one in a freezing mixture, warming the other to a temperature of about 40° C., by immersion in hot water, and boiling the third. On testing for sugar, the last will be found not to contain any, the first very little, and the middle one a considerable quantity.

The result of the presence of acid in a mixture of starch and saliva may be shown in a similar manner. Into one test-tube let starch and saliva be put; into another the same mixture, with a dilute solution of hydrochloric acid; into a third, put another portion of saliva and starch, but with some ordinary hydrochloric

acid. Neutralise these solutions, and test for sugar ; it will be found in nearly equal quantities in the first and second tubes, but will be absent in the third.

This experiment proves that the acid of the gastric juice does not arrest the action of the saliva on starch.


The active principle ptyalin may be obtained from the salivary glands by aid of glycerin, which readily dissolves it; by the addition of alcohol, it is precipitated.

The masticated food passes down into the stomach, and there undergoes another change ; the albuminoid constituents are converted to peptones, and gelatin loses its property of gelatinising.

It will be remembered that albumin was mentioned as being incapable of passing through the membrane of the dialyser ; by conversion into peptones, however, it will readily osmose, and is then in a condition to be absorbed by the intestines.

The agent which produces these changes is the *gastric juice*, secreted by the follicles of the stomach. It is a fluid containing about one per cent. of solid matter, and a free acid, probably lactic ; the active principle is *pepsin*.

It is a difficult operation to form a fistula in a dog's stomach and thus obtain a quantity of gastric juice large enough for experiment. A very good artificial



fluid can be prepared by scraping off the mucous membrane from the stomach of a recently-killed animal, rubbing it down with sand in a mortar, and filtering; the filtrate is gastric juice, to which should be added an equal quantity of 0·2 per cent. hydrochloric acid solution.

This product may be used for a series of experiments on the digestion of various articles of food, the experiments to be conducted in test-tubes immersed in a bath at 40° C.

The action of acids and alkalies, extreme cold and heat, &c., may also be tried. It will be found that a temperature of 35° C. to 40° C. aids the digestive power of the gastric juice.

Acetate of lead and chloride of platinum precipitate pepsin.

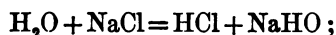
Neither pepsin nor hydrochloric acid alone will digest albumin, but mixed as stated above they do so readily, and produce peptones. There are several peptones; the most important, the last of the digestive process, does not give the reactions of albumin, and passes through the dialyser, showing that it is totally changed.

Pepsin is not used up in the process of digestion; it simply acts as a ferment.

The stomach does not cease to secrete gastric juice when the animal dies, so that a stomach may be



digested in its own gastric juice, an important fact in medical jurisprudence. The reasons stated in explanation of the fact that gastric juice does not injure the living stomach are (1) that the alkalinity of the blood circulating through the vessels preserves it; (2) that an interchange takes place in the follicles of the stomach between water and chloride of sodium, which results in the formation of free acid for digestive purposes, and caustic soda, which prevents the acid from acting injuriously, and is carried away by the blood into the liver, to be utilised for the bile, thus—




or, as suggested by Ralfe, an interchange between chloride of sodium and carbonate of sodium.

After the food has been converted into a pul-taceous mass, known as chyme, it is propelled by peristaltic action into the duodenum, and there meets the bile and pancreatic fluid.

The *Bile* is a most complex fluid secreted by the liver. It is a thin liquid, frequently ropy, with a golden yellow colour, and a specific gravity of 1.026. The gravity and composition vary greatly; it contains about 90 per cent. of water.

Bile has in its composition mucus, cholochrome, biliary acids, cholesterine, and salts of sodium, with some copper.



Bile freed from mucus will remain undecomposed for an indefinite period. The mucus may be separated by the addition of dilute alcohol and subsequent filtration; freed from mucus, it may be tabulated thus:—

Cholochrome, or colouring matter.

Glycocin      }  
 Taurin        } Cholic acid = { Glycocholate } of soda.  
                       }                        { Taurocholate }

Cholesterin.

Salts.

The presence of the colouring matter of bile may be tested with nitric acid, which produces a play of colours in prismatic order. The experiment is best performed on a porcelain capsule. One drop of bile should be placed beside one drop of fuming nitric acid, and the capsule inclined so that the one may run into the other; at the point of contact, bands of colour are seen. Fluids containing alcohol produce a similar change, so that this cause of fallacy must be guarded against.

The various colours seen in the above experiment are due to the production, by oxidation, of biliverdin ( $C_8H_5NO_2$ ) and other derivatives.

Cholochrome or bilirubine has the formula  $C_8H_5NO_2$  (Thudichum); it is soluble in chloroform, by which it may be obtained both from bile and gallstones.

It is sometimes necessary, in testing for choleochrome in urine, to precipitate with milk of lime, and extract the precipitate with alcohol and sulphuric acid, which, by prolonged boiling, becomes green, oftentimes blue, especially if nitric acid be present, from the choleocyanin of Dr. Thudichum having been formed.

The identity of the colouring matter of the bile and urine with that of the blood, is fairly established by various experiments and spectroscopic observations.

To test for bile acids, mix some bile with water, and add an equal quantity of syrup; then add a few drops of strong sulphuric acid, and shake the tube; a beautiful purple colour will be developed.

This is known as Pettenkofer's test. It gives a very characteristic spectrum—a line at D and the spectrum cut off at G (*see* Spectrum chart).

The methods for the separation of the various biliary constituents are too lengthy for notice here.

Cholesterin is readily prepared from gallstones, some of which consist almost entirely of this substance. Some powdered gallstones are treated with boiling alcohol, and filtered whilst hot; on cooling, the cholesterin separates out in rhombic scales of pearly lustre; it is soluble in ether, melts at  $145^{\circ}\text{C.}$ , and has a formula  $\text{C}_{26}\text{H}_{44}\text{O}$ ,  $\text{H}_2\text{O}$ ; with dilute sulphuric acid it becomes violet; rubbed up with strong

sulphuric acid, on the addition of chloroform, it becomes red, and runs through violet, blue, green.

The action of bile is somewhat obscure; it emulsifies fat, precipitates pepsin, and probably acts as a natural purgative by irritation of the muscular tissue of the intestine; it also serves as a disinfectant, preventing decomposition of the fæces.

The amount of bile secreted varies in different animals; it is generally estimated per body weight; it has been suggested more wisely that the liver weight should be taken as the prime factor (*Thudichum.*)

The liver re-absorbs bile, and never secretes it at a high pressure.

One of the most important subjects connected with the liver, is that of glycogeny; the liver forms in itself a substance (glycogen) which, as its name implies, is a sugar producer. Sugar exists in the system in several forms, *i.e.*, as milk sugar, as inulin, as hippuric acid, derived from glycocin or jelly sugar, distinct from glycogen or sugar producer.

If a portion of the liver of a dead animal be cut up into small pieces and boiled in water, and the solution tested for sugar in the following manner, considerable quantities will be found.


A portion of the sugar-containing fluid is rendered alkaline by the addition of an equal quantity of liquor

potassæ, a few drops of a solution of sulphate of copper are added, which occasions a precipitate of the blue hydrated peroxide of copper; boil the mixture; if sugar be present it will reduce the hydrated peroxide to anhydrous suboxide of copper, which is a bright yellow or orange-coloured powder.

To ascertain quantitatively the amount of sugar present, it is necessary to have a solution of copper, preferably the potassio-tartrate, which contains to every cubic centimetre of fluid as much of the salt as will be reduced by a definite quantity of sugar.\*

Given, then, a solution of copper salt, in which every cubic centimetre represents, say, 0.05 gramme of sugar, it is necessary to fill a graduated burette with the test, and then to drop it gradually into a measured quantity of sugar solution kept boiling in a porcelain basin; when the solution becomes tinged slightly blue the sugar is then entirely exhausted, and the copper reduced to suboxide. To find the point at which the blue colour is permanent, it is necessary to remove the lamp occasionally, that the precipitate may subside, and the clear fluid be observed; this found, the number of cubic centimetres of copper solution used, mul-

\* These solutions may be obtained, ready for use, of Mr. Sutton, Norwich.



multiplied by 0.05 gramme, gives the amount of sugar contained in the measured quantity of sugar solution used.

The sugar found in the liver is undoubtedly produced from a substance which is rapidly converted to glucose under all circumstances.

If we take an animal some two hours after a full meal, for glycogen is then most abundant, suddenly kill it, tear out the liver quickly, cut it into pieces, and throw it into a basin of water kept boiling by means of a lamp beneath, we shall arrest the action which would otherwise occur, *i.e.*, that of the conversion of the glycogen into sugar; after the liver is well boiled, take out the pieces and mash them up, return to the original water, and boil again.

Filter when cool, add some dilute hydrochloric acid and saturated solution of mercuric iodide to precipitate albumin, filter again, and to the filtrate add absolute alcohol; a precipitate of glycogen occurs.

Acetic acid added to the first filtrate sends down the glycogen in an impure condition.

*Glycogen* ( $C_6H_{10}O_5$ ) is amorphous, soluble in water; iodine colours it red, and by boiling with dilute hydrochloric acid it is converted to dextrine; ferments, as the ptyalin of the saliva, convert it immediately to sugar, as may be shown by mixing some saliva and


glycogen in a test-tube, and testing with Trommer's test.

Glycogen is formed wholly in the liver, and is as rapidly converted to sugar, which is carried away by the blood circulating through this organ; sugar may be found in the blood by the process described above, if the precaution be first taken of rubbing it down with some animal charcoal, and filtering; the filtrate contains the sugar.

Sugar, therefore, is not a natural secretion of the liver, but is constantly there by the rapid conversion of the glycogen.

If we take the liver of a recently-killed animal, and divide it into several portions, we shall find that the portion operated on first will contain less sugar than the portions used some time after death, and that the longer the piece has been dead before it is tested, the greater the amount of sugar contained; this demonstrates the progressive formation of sugar in the liver, in direct proportion to the time that has elapsed since death.

If we connect a syringe with the portal vein, and wash the liver with water until the washings do not yield a result with the sugar test, and then leave it for a short time, we shall find that sugar is present on testing the water in which a piece may have been



boiled; this is further evidence in favour of the above facts.

From what elements glycogen is formed it is difficult to say, for it is found alike in the liver of animals fed exclusively on meat as in those of the herbivora; a starch diet increases the amount considerably, as may be tested on two rabbits, one being fed on greens and the other with corn; by prolonged starvation it may be entirely removed from the liver.

The use of glycogen in the economy is uncertain. It may be connected with the supply of force to the muscles, as blood which has passed through muscles in action contains less sugar than that which is about to enter.

The liver and blood contain ferments which convert glycogen into grape sugar.

The *pancreatic juice* is poured out into the duodenum, and exerts a further action on the partly-digested contents; it emulsionises fats, liberates the fatty acids, converts starch into sugar, and digests fibrin, forming peptones, and afterwards producing leucine and tyrosine.

The ferment, pancreatin, may be separated from the gland by first soaking in alcohol, and then digesting in glycerin; the solution may be used as an artificial juice for experiments.



The intestinal juices are not so readily obtained, nor are the purposes which they serve so well known; they have, however, a use, as has been shown by the introduction into and localisation in the intestines of portions of food; ultimately these have been found digested. From the mass of chyme which is produced by the varied processes we have briefly surveyed, the villi of the intestines draw the milky fluid known as chyle; it is conveyed by the lacteals to the receptaculum chyli, there to ascend by the thoracic duct to the left subclavian vein, to commingle with the blood and supply the necessary waste of tissue.

Chyle coagulates into white fibrin and turbid serum with a strongly alkaline reaction; it is crowded with white corpuscles. Casein may be precipitated from it by acetic acid and albumin by boiling; peptones may also be obtained from it by dialysis.

The mass of food which has been drained of its nutrient elements is forced downwards by a peristaltic action of the intestines, the action of which may be seen in a recently-killed animal, and passes out into the draught; it contains changed biliary matters and other substances obtained from the intestinal secretions. There are some interesting products to be obtained from fæces, noticeably excretin and excretolic acid, discovered by Marcet.

## BLOOD.

The elaborated food passes into the venous circulation, and enters at once into the right auricle, from whence it is forced into the right ventricle, from thence into the lungs, where it meets the air necessary for its oxydation. It is returned from the lungs to the left auricle; it then passes into the left ventricle, to be forced into the systematic circulation.

There are noticeably two kinds of blood—the oxydised or arterial, and the deoxydised or venous.

The arterial blood, as it appears in the system, or immediately after it is drawn from the body, is a red fluid, but examined under a tolerably high power of the microscope, it is seen to consist of a colourless fluid or serum, in which may be seen to float corpuscles of two kinds, known as red and white. The red are only capable of transmitting red light when many of them overlies one another, so that virtually they are not red; the coloured corpuscles are about  $\frac{1}{3800}$  inch in diameter; they consist of biconcave discs. The colourless corpuscles are much larger, but fewer in number, than the coloured; they are globular masses of protoplasm, and are capable of changing their forms by protrusions of parts of the mass, from which peculiarity they are called amœboid cells.

Water acts on blood corpuscles generally by causing them to swell, the contour to become more marked, and the nucleus more distinct; salt water causes them to shrink, and the edges to become crenated. Acids remove the colour, and cause them to swell; the nuclei of the coloured cells are rendered distinct. Alkalies dissolve the colourless corpuscles, and distort the coloured ones; boracic acid renders distinct the nucleus, and in many instances causes it to withdraw from the corpuscle; tannin and carbonic acid gas act similarly. Klein considers these results may be explained by coagulation.

When blood is allowed to flow from a vein or artery into a vessel, and set aside, it coagulates. After a time, the clot contracts, and a yellowish fluid, serum, oozes out from it, and finally solidifies on the top of the other, so that if the clot be cut in halves it presents two parts, a red and yellow.

This coagulation is due to the formation of a substance, fibrine, which entangles the blood corpuscles, and finally contracts, forcing out the serum, which subsequently also coagulates.

The liquor sanguinis, in which the corpuscles float, is isolated with difficulty, but sulphate of soda in solution will retard coagulation sufficiently to allow filtration from the corpuscles.

Another method, and one which may be employed when the corpuscles are required, as well as for the separation of plasma, is to dilute mammalian blood, preferably that of the horse, with ten volumes of a 2 per cent. chloride of sodium solution, which prevents coagulation, and allows the corpuscles to settle to the bottom of the fluid.

To obtain the liquor sanguinis or plasma for comparative testing, it is necessary to use freezing mixtures, and to proceed with great care. It separates into clot and serum, and also produces fibrin when diluted with water.

The formation of *fibrin* is said to be due to the combination of two kinds of albumin, termed respectively fibrinoplastic and fibrinogenic substances; the former is identical with paraglobulin, and is precipitated from solution by carbonic acid; when added to a fluid which contains fibrinogenic matter, such as hydrocele fluid, fibrin is formed; fibrinogenic substance can be obtained from its solution by saturating with chloride of sodium, collecting the precipitate, and dissolving in distilled water.

It was propounded by Heynsius that fibrinoplastic matter was contained in the coloured corpuscles. It is probable that the substance is largely contained in the

colourless corpuscles, but experiment does not prove the former theory.

Fibrin is also produced from albumin, by allowing it to fall into water, and to remain suspended in that fluid for a day or two. An electric current, too, also determines its formation, but, according to Goodman, only in the presence of water.

Fresh fibrin decomposes peroxide of hydrogen.

Blood, although containing as it does the elements for the production of fibrin, does not coagulate while in contact with the living body; thus if a frog's heart be removed coincidently with some blood, it will be found that some time after the blood has coagulated, that in the heart will be fluid. Cold, as we have seen, retards coagulation, as does dilution with water or solutions of the neutral salts. Coagulation is accelerated by shaking (a method sometimes used for roughly estimating the fibrin), a temperature of more than 50° C., the electrical current, and contact with air.

Heat, cold, dilution with water, electrical discharges or currents, render the blood transparent or lakey; this is due to the removal of the hæmoglobin from the corpuscles.

*Hæmoglobin* is a constant constituent of the corpuscles, and may be obtained by allowing them to sub-

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side in a saline solution kept cold, collecting, washing with water and ether, filtering, and subjecting to intense cold. It will be noticed that the water dissolves the colouring matter which crystallises out in the cold.

Blood from certain animals requires a slight addition of alcohol to produce the crystals.

This constituent contains the iron of the blood; 0.43 per cent. may be obtained from the crystals. On ultimate analysis the elements will be found in such proportion that a formula of  $C_{600}H_{960}N_{54}FeS_3O_{177}$  may be calculated, giving an atomic weight of 13,280 (Thudichum). This is perhaps the highest atomic weight known, and, contrary to the general law, hæmo-crystallin is an exceedingly stable body, so much so that it may be found to exist in putrefying blood of long standing.

Hæmoglobin is the substance which carries oxygen to the various tissues, after having received it from the air in the lungs. So great is the affinity of this body for oxygen that it may be almost said to exist in a separate form when combined with this gas, as it is most difficult to keep in its reduced form. Reduction may be effected by the addition of re-agents, such as hydrogen sulphide, or a mixture of ferrous sulphate with tartaric acid and ammonia in excess. The colour

of oxyhæmoglobin is bright red, the hue of arterial blood, while reduced hæmoglobin assumes a deeper and purplish hue corresponding to venous blood. Certain gases which are known to produce death when breathed, do so in some instances as direct poisons, combining indissolubly with the hæmoglobin, not acting merely by the exclusion of oxygen. Of these, carbonic oxide and hydrocyanogen may be quoted as examples. The evidence of these facts rests with the spectroscope, for if blood mixed with various reagents be applied to that instrument, new bands are produced in cases where fresh combinations occur.

The oxygen of the hæmoglobin is but loosely held, and may be wholly removed by the Torricellian vacuum.

It is precipitated by alcohol, is indiffusible, coagulates when heated, and is soluble in water.

Hæmoglobin gives a decided reaction with the following test, one much advised in medico-legal cases:—A drop of tincture of guaiacum is allowed to fall on a piece of absorbent paper; when dry, the blood or solution of hæmoglobin is added, and a solution of peroxide of hydrogen ( $\text{H}_2\text{O}_2$ ); a blue colouration, due to the oxidation of the guaiacum, immediately occurs.

This test is, however, not to be depended on, and

is superseded by two others, viz., the hæmin test and the spectroscopic appearances.

When oxyhæmoglobin is allowed to intercept the rays of light passing to the prism of a spectroscope, a change takes place in the previously continuous spectrum, consisting in the absorption of a portion of the light, and, consequently, in the production of shadows or bands, in this case taking their position between the D and E lines of Fraunhofer; if the solution be agitated with some of the reducing agents already mentioned, a change takes place, in which the two bands become merged into one.

The spectra of blood, combined with the various gases just mentioned, are definite and easily recognisable.

A method for estimating the hæmoglobin in a sample of blood consists of comparing the transparency of a layer of a certain thickness with another containing a known quantity.

*Hæmin* crystals may be obtained from blood, thus : — A small quantity of dried blood is placed on a microscopic slide, and a few crystals of salt are then added, and a cover-glass placed over them; a drop of glacial acetic acid is allowed to enter from the side, and the slide carefully warmed. As soon as the acid



is nearly evaporated, abundant crops of crystals are seen (Klein).

*Hæmatin*, one of the constituents of hæmoglobin, may be obtained by the decomposition of hæmin, which is considered by some to be a hydrochlorate of hæmatin; by the action of acetic acid, it is converted into acid-hæmatin.

The estimation of the gases of the blood is an exceedingly difficult and complex operation; it is necessary to remove them by means of a Sprengel air-pump.


Bernard estimates the oxygen by displacement with carbonic oxide.

The blood is the medium by which the carbonic acid resulting from the waste products of the body makes its exit at the lungs; it is estimated that daily about  $8\frac{1}{4}$  ozs. of carbon are exhaled from the lungs in this form.

#### SECRECTIONS.

*Milk*.—This fluid is the most important in the animal economy, necessary as it is to support the life of the young animal. A knowledge of its composition is of considerable use.

Milk is secreted by the mammary gland, the presence of which determines the name of the class mammalia.



The secretion contains all the necessary material for supplying the body with nourishment, viz., an albuminoid substance of a complex nature, casein; a fat, butter; a sugar (lactose), and salts, as phosphate of calcium, &c.

Milk is a white fluid, of a specific gravity of 1.031, viewed by the microscope, it presents the appearance of numerous globules floating in a clear fluid; these globules consist of fat, encased in an envelope of casein.

Colostrum, or milk obtained directly after the delivery of a female, is of higher specific gravity, and thicker and yellower than ordinary milk; it contains albumin and some corpuscles, which exhibit movements; it has a purgative action on the newly-born infant.

Milk when fresh has an alkaline reaction with test-paper, which is probably due to the consideration that casein may be regarded as closely resembling alkali-albuminate. It was long thought to be wholly this substance, but recent researches have shown that it consists of an albuminous body in addition.

Casein does not precipitate on boiling, but it is precipitated by acetic acid; it curdles spontaneously from the formation of lactic acid, which neutralises the

alkali. The filtrate obtained after the precipitation of casein yields albumin on boiling.

The casein of human milk is not precipitated by acetic acid. The fat of milk, butter, separates if the milk be allowed to stand undisturbed; not wholly, however, unless it be briskly agitated with ether. In churning, the caseous envelopes are broken, and the fat aggregates.

To estimate the fat, add to milk some caustic soda, and then agitate with ether; or the milk may be evaporated to dryness, and the residue exhausted with ether or benzol; in either case, the charged menstruum is removed by a pipette, and evaporated to dryness in a capsule; the residue is the fat.

Lactose, or sugar of milk ( $C_{12}H_{24}O_{12}$ ), occurs exclusively in milk. It is secreted in the largest quantities by herbivora, but also by animals fed on meat. It is a hard gritty body, crystallising in four-sided prisms, terminating in four-sided pyramids; sparingly soluble in cold water, insoluble in alcohol. It turns the ray of polarised light to the right, does not ferment, but by boiling with acids is converted to galactose, which is fermentescible. It reduces copper salts in alkaline solution.

The inorganic salts of milk are only to be obtained by evaporation and incineration; they consist, as pre-



viously mentioned, of phosphates, chlorides, &c., of the alkalies and alkaline earths.

The percentage composition of milk varies at different times in the day and according to the food and drink supplied to the animal; the importance of this fact will be seen, when it is noted that herbs, grass, or artificial food supplied to cattle, will frequently determine the flavour and colour of the milk and butter derived from them.

That drugs are removed from the blood by the mammary gland is evinced by the records of deaths of infants from poisoning with strychnine through the mother having taken medicinally tincture of nuxvomica.

Asses' milk is said to resemble human milk in its composition more than that of any other animal.

Cow's milk contains more casein and less sugar than human milk; therefore, to reduce the former to the proper condition for children's food, one-third water should be added, and about half-an-ounce of sugar of milk to the pint.

Dr. Voelker ('Pharm. Jour., March 14, 1874), gives the following table of daily variation:—

COMPOSITION OF MORNING AND EVENING'S MILK PRODUCED ON THE  
ROYAL AGRICULTURAL COLLEGE FARM, CIRENCESTER.

		Percentage of					
		Water	Butter (pure fat)	Casein and Albumin	Milk- sugar	Mineral Matters (a-h)	Nitrogen
January .	Morning	87.70	2.60	2.94	5.82	.94	.47
	Evening	87.40	2.28	2.87	6.56	.89	.46
February	Morning	87.50	2.58	3.44	5.44	1.04	.55
	Evening	86.40	3.53	3.37	5.56	1.14	.54
March .	Morning	88.60	2.71	2.43	5.35	.91	.39
	Evening	88.16	2.96	2.62	5.55	.77	.42
April .	Morning	87.50	3.15	2.94	5.60	.81	.47
	Evening	89.00	2.47	2.69	5.08	.76	.43
May .	Morning	88.20	2.42	3.12	5.49	.77	.50
	Evening	87.80	2.71	2.87	5.85	.77	.46
June .	Morning	87.30	3.05	3.00	5.89	.76	.48
	Evening	87.30	2.94	2.87	6.05	.84	.46
July .	Morning	88.70	2.22	2.94	5.38	.76	.47
	Evening	87.80	3.61	2.81	5.10	.68	.45
September	Morning	89.91	1.99	2.94	4.48	.64	.47
	Evening	90.70	1.79	2.81	4.04	.63	.45
October .	Morning	87.60	3.90	2.87	4.84	.79	.47
	Evening	90.30	2.99	2.37	3.76	.58	.38
November	Morning	87.10	3.41	2.94	5.41	1.14	.47
	Evening	86.20	3.78	3.19	5.68	1.15	.51
December	Morning	86.70	3.74	2.87	5.92	.77	.46
	Evening	86.00	4.12	3.62	5.46	.80	.58

L'Heretier gives the following as the composition  
of human milk:—

Water . . . . .	86.8
Butter . . . . .	4.2
Casein . . . . .	1.2
Sugar . . . . .	7.4
Salts . . . . .	0.4
	<u>100.0</u>

## URINE.

The most variable fluid excreted by the animal body is the urine. This must be evident to anyone who for a moment considers the variety of changes to which it is constantly being subjected; thus the increased action of the skin resulting in perspiration, reduces the amount of liquid to be excreted by the kidneys, and therefore raises the percentage of solid matter in the urine; the ingestion of water, or any fluid, lowers the specific gravity; and the waste of tissue, consequent on disease, disordered function of any kind, or even healthful exercise, adds to the solid constituents.

Moreover, its complications are in some instances inexplicable, for we know that it contains substances yet unaccounted for; again, odorous bodies are so readily taken up and excreted by the kidneys, that infusion of coffee ingested will communicate its odour exactly to the urine, as will many drugs; turpentine rubbed on the skin will produce an odour of violets in the urine, and iodide of potassium taken internally, or iodine painted on the skin, will make their appearance in the urine within a very few minutes after the application.

From these statements it will be seen that innumerable substances may be present in the urine, and also that but simple causes will effect great variations; nevertheless, we are fairly justified in saying that we know more intimately the constitution of this fluid than that of most other animal secretions, and that this knowledge has been found to be more available as an auxiliary to the diagnosis and treatment of disease, than information of a similar nature respecting other secretions, or fluids of animal origin.

The *specific gravity* of urine in health varies from 1.005 to 1.030; either of these extremes, however, would lead one to a suspicion of the presence of some abnormality, the usual or average specific gravity being about 1.020.

The determination of the specific gravity is useful, as giving the solid residue. Much has been written on the errors likely to accrue from this mode of calculation, but no easier method has been devised; thus, Wanklyn has suggested evaporating to dryness a given quantity of urine and weighing for solid residue, then incinerating, and weighing for salts; this is definite, and gives the ratio of organic matter, but it is not available for general purposes, as occupying too long a time, and requiring laboratory arrangements; besides which it yet remains to be proved whether evaporation and

incineration may not deprive the residue of some salts and volatile bodies which would add to the specific gravity of a fluid.

The methods employed for taking the specific gravity of urine are similar to those used for other fluids; it is most conveniently taken either in the ordinary bottle or with a form of hydrometer called a urinometer, and graduated for gravities between 1·000 and 1·060, water being taken as 1·000; the temperature of 0° C. or 60° F., should be used as the standard temperature at which to take the gravities; this is an important item, as one degree more or less will greatly alter the apparent weights, and in the case of diabetes melitus and other diseases may mislead as to the effects of drugs administered.

In estimating the constituents of urine, or in taking specific gravities, it is absolutely necessary to proceed only with the urine passed during a period of twenty-four consecutive hours, and subsequently blended. From what has been said above, it is evident that the urine passed in the morning may be different from that at mid-day or eventide, and therefore, to observe accurately from day to day, the different portions must be mixed.

The reaction of urine with test-paper is acid, due probably to the presence of uric and hippuric acids,



according to Thudichum of kryptophanic acid, and to others of free carbonic acid or acid phosphate of sodium.

After exposure to the air for some time, urine becomes alkaline, emits a fœtid ammoniacal odour, and deposits various salts; this is due to the formation of carbonate of ammonia from the splitting up of the urea, the behaviour of which body is described, p. 10.

The normal constituents of urine are—urea, uric acid, hippuric acid, colouring matter and salts, more particularly common salt, ammonia, and potassium chlorides, phosphates of calcium and magnesium, acid phosphate of sodium, sulphates of potassium and sodium.

Urine may contain abnormal constituents, as albumin, grape sugar, bile acids, bile pigments, lactic acid, blood, pus, oxalate of lime, cystine, &c.

The addition of a solution of nitrate of silver to urine determines a mixed precipitate, which, if treated with nitric acid, will remain as pure chloride of silver.

To determine the quantity of chlorine present in a given sample, it is necessary to evaporate to dryness with pure nitrate of potassium, dissolve, and precipitate with nitrate of silver, collect, dry, and weigh the precipitate.

The *phosphoric acid* of urine is precipitated by molybdate of ammonia on boiling; the earthy phosphates are precipitated by ammonia, but to estimate quantitatively it is necessary to have a standard solution of uranium acetate, 1 c.c. = .005 grammes of phosphoric anhydride; 50 c.c. of urine are taken and boiled with 5 c.c. of a solution (1—10) of sodium acetate acidified with acetic acid; the standard solution of uranium acetate is now added from a burette, and after the addition of each successive portion, a drop of the fluid is taken on the end of a glass rod and mixed with a drop of solution of potassium ferrocyanide on a porcelain slab; if excess of uranium has been added, a brown precipitate occurs; the number of c.c. used multiplied by .005 gives the amount in grammes of  $P_2O_5$  in the 50 c.c. of urine taken.

*Sulphuric acid* is determined by precipitation with chloride of barium, collecting, drying, and weighing.

*Urea* may be demonstrated in urine by various methods, such as evaporating a portion to dryness and extracting with alcohol; it is more readily shown, however, by adding strong nitric acid to urine, which determines the formation of nitrate of urea, a crystalline body less soluble than urea.

The quantitative methods of determining urea are

faulty; the method usually employed is known as Liebig's process.

When mercuric nitrate is added to a solution of urea a precipitate is formed, consisting of  $(\text{CH}_4\text{N}_2\text{O}, 2\text{HgO})$ ; if, however, chlorine or phosphoric acid be present, as in urine, then they also cause precipitates, so that certain corrections have to be made before the result is obtained; thus, in estimating urea in urine, 30 c.c. are taken and mixed with 15 c.c. of baryta mixture (two volumes of saturated solution of barium nitrate with one volume of a like solution of hydrate of baryta); the precipitate formed is separated by filtration, and 15 c.c. of the filtrate used for the determination; 10 c.c. of urine are contained in this mixture. The precipitate produced by this reaction consists of sulphates and phosphates.

A standard solution of mercuric nitrate (1 c.c. = .01 grm. of urea) is now added from a burette, and after the addition of every few drops a portion of the fluid is removed on the end of a glass rod and added to a drop of solution of carbonate of soda; if the urea is all precipitated, and the mercury is in excess, then a yellow precipitate will be found in the drop of sodic carbonate solution.

The number of c.c. used, minus 2, and multiplied by 0.01, represents the amount of urea. The object of

deducting two is to allow for the sodium chloride, which is generally present in sufficient quantities to decompose that proportion of the test.

Russell and West describe a simple method founded on the process of Davey, which may be used in the wards of hospitals ('*Journal Chemical Society*,' 1874). The apparatus consists of a tube about nine inches long, with a bulb at the closed end, and a slight constriction above the bulb, capable of being closed with a long glass rod having a short piece of caoutchouc tube slipped over the end. The open end of the tube is fitted by means of a perforated cork into the bottom of a small pneumatic trough. Five c.c. of the urine under examination are introduced into the bulb, whose capacity is about 12 c.c., washed in with a little water, and then closed by the glass rod. The tube is now filled up with a solution of sodium hypobromite, prepared by dissolving 100 grms. of sodium hydrate in 250 c.c. of water, and adding 25 c.c. of bromine. The trough is filled with water, the glass rod is withdrawn, and an inverted graduated tube, previously filled with water, is at once brought over the mouth of the laboratory-tube. The hypobromate now acts on the urea, liberating nitrogen, which passes into the graduated tube, and is there measured. If necessary, the reaction, which usually occupies about ten minutes,

may be accelerated by gently heating the tube. It is found that the amount of nitrogen given off from a given weight of urea is about eight per cent. less than the theoretical, but, by a curious coincidence, the corrections, which would have to be made for the reduction in the volume of the gas for aqueous vapour and a temperature of 65° F., compensate for this; the variation caused by change of atmospheric pressure is so small that it may be disregarded. In practice, it is found advisable to graduate the tube so as at once to give either the percentage of urea present, or the number of grains per fluid ounce.

Dr. Thudichum believes that an acid body contained in the urine has a urea value of  $1\frac{1}{2}$  per cent.

To determine uric acid it is necessary to add dilute hydrochloric acid; collect the precipitate dry, and weigh.

*Hippuric acid* is not easily obtained from human urine; but the ingestion of benzoic acid, as mentioned elsewhere, produces large quantities of it.

When horses and oxen are exercised, the hippuric acid naturally contained in their urine is changed to benzoic acid, and is only excreted unchanged when they are kept in a state of rest.

The processes for the separation of kreatin, indican,

etc. from the urine are too lengthy for the general student to attempt.

The colouring matter of the urine is a complex body, due probably to some changes in the colouring matter of the blood. We find in febrile and other states the urine highly coloured, due, no doubt, to the continued waste of hæmatin. The colouring matter is generally removed from urine by precipitation with lead salt.

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*Sweat* contains about one per cent. of solids, as chloride of sodium and urea; it is also said to contain free lactic acid, lactates, butyrates, and acetate of ammonia. Carbonic anhydride is said to be exhaled from the skin. Moriggia holds that the sweat of carnivora is acid, that of herbivora alkaline.

The skin is capable of absorbing various soluble substances placed in contact with it.

*Tears* are saline, containing principally sodium chloride.

*Semen*, characterised mainly by the spermatozoa, has as yet yielded but little information to the chemist.

The *menstrual fluid*, occurring periodically in the female, consists of altered blood; its acidity is due to the presence of vaginal mucus; collected by means of a

speculum it cannot be differentiated from ordinary blood ; it is somewhat darker in colour, more fluid, and does not so readily coagulate ; that it does coagulate is amply proved.

*Cerumen*, or wax, secreted by the ear, is composed largely of sebacic acid, with a trace of colouring matter.

*Mucus* is secreted by the mucous membranes. It contains a substance, mucin, which precipitates and contracts under the influence of acetic acid ; mucin is also found in foetal connective tissue and in tendon.

*Bone* consists of earthy matter one-third, and organic matter two-thirds. When a bone is soaked in dilute hydrochloric acid the earthy matter is dissolved out and the ossein or organic matter remains, still retaining the original form of the bone ; if a bone be subjected to intense heat, the organic matter is consumed, and a brittle white substance, the inorganic residue, remains ; this also retains the original form of the bone.

The earthy matter consists of tribasic phosphate of calcium, carbonate of lime, phosphate of magnesia, and other salts.

The organic matter yields gelatin when boiled in water, especially under pressure in a Papin's digester.

*Teeth* are similarly constituted with bone, except

that the organic matter is in less proportion; the enamel contains only two per cent.; traces of fluorine and silicon are found in the teeth.

In old age bones contain more salts, and are more brittle; in young children the bones are elastic, and contain more organic matter.

Hair, nails, skin, horns, hoofs, and feathers are nearly identical in composition, containing a gelatinous body, removable by boiling, and which bears the name keratin.

*Muscles* contain fibrin, an acid form of albumin (syntonine), myosin, extractive matters, kreatin, sarkin, xanthin, uric acid, inosic acid, glucose, inosite, lactates, and salts.

The odour developed in meat by roasting is known by the name of ozmazome.

*Pigment* does not occur in large quantities; from its general behaviour with reagents it greatly resembles free carbon. The colour of dark hair is said to be due to manganese.

#### THE BRAIN.

This organ consists of so many individual parts that the chemistry of it as a whole is of little value, while the difficulty experienced in separating parts



almost precludes the hope of ever definitely marking out its constituents.

It contains, as a whole, cerebrin, lecithin, neurin, cholesterin, and other bodies; it contains an ash percentage of 1.74; the ash of grey matter is alkaline, of white matter acid. The brain contains a large quantity of phosphorus, as phosphoric acid, both free and combined.

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